Environment monitoring technical report for the SON cage fish culture site at Bugungu, Napoleon Gulf, northern Lake Victoria, November 2013

Contributing Scientists:

Dr. L.M. Ndawula (Activity Leader & Report Editor)

Mr. H. Ocaya (Heavy metals and Organic pollution)

Mr. G. Magezi (Algal Community, Physico-Chemical parameters)

Ms. J. Naluwairo (Nutrient status)

Mr. V. Kiggundu (Zooplankton community)

Mr. W. Pabire Gandhi (Macro-benthic community)

Ms S.Musubika (Macro-benthic community)

Ms. G. Namulemo (Fish Community)

Mr. M. Olokotum (Fish Community)

Ms. M. Nsega (Fish Community)

Mr. C. Nuwahereza (Cage fish dynamics)

December, 2013

EXECUTIVE SUMMARY

Source of the Nile Fish farm (SON) is located at Bugungu area in Napoleon Gulf, northern Lake Victoria. The proprietors of the farm and the National Fisheries Resources Research Institute (NaFIRRI) have an established collaborative arrangement where NaFIRRI provides technical back-stopping to enable quarterly environment monitoring of the cage site as a mandatory requirement of the National Environment Management Authority (NEMA). The agreed study areas are selected physical-chemical factors (water depth, water transparency/secchi depth, water temperature, dissolved oxygen, pH, conductivity, and nutrient status), algal community (including primary production), aquatic invertebrates (zooplankton and macro-benthos) and the fish community. This report presents field observations made during the fourth quarter (October-December) field survey undertaken during December 2013; along with scientific interpretation and discussion of the results in reference to possible impacts of the cage facility to the water environment quality and aquatic biota.

The SON cage study sites were coded as '*downstream of the cages'* (DSC), *'within the cages'* (WIC) and *'upstream of the cages'* (USC). Coordinate locations of the sampling points were determined with a GPS device. Physical-chemical parameters were measured in-situ with a pre-calibrated hydrolab at each site. A digital Echo Sounder was used to determine the total water depth. A black and white Secchi disc was used to determine water column transparency. Water samples for determination of nutrient and algal status were collected with a Van dorn sampler. Selected dissolved nutrients (SRP, NO_2-N, NH_4-N and TSS) were analyzed by spectrophotometric methods. Zooplankton community was sampled with a Nansen plankton net of 0.25m mouth opening and 60µm Nitex mesh. The macro-benthic community was sampled with a Ponar grab of 238cm^2 open jaw area. All samples were taken in triplicate at each sampling point. Invertebrate samples were microscopically examined for species composition, distribution and abundance patterns. The Fish community was sampled with three fleets of gill-nets of varying mesh sizes; fish caught were taxonomically identified and species numbers and weight recorded per site. Observations were also made on aspects of parasites, biology and ecology of the fishes.

Compared to previous surveys, there were no marked variations in water depth across the study sites, indicating no evidence of possible sedimentation. Secchi depth did not vary much (1.5-1.8m) across sampling sites and the site with cages (WIC) had the deepest reading indicating no possible impact of the fish cages on the natural environment. Measured turbidity level between 1.57 and 4.59NTU is considered low compared to 200 NTU which is known to impact on fish negatively. Dissolved oxygen concentration ranged between 6.94 and 9.10mg/L, a range well above the minimum level (3mg/L) for fish production. Measured values of pH ranged from 6.88 to 7.8 across all the three sites and this range was within acceptable pH conditions for cage culture. The measured water temperature of 25.0 to 26.8°C was within the optimal range fish growth and spawning. Conductivity measurements (111.3-120.0µScm^{-1} were normal levels commonly recorded in water bodies in Uganda and there was therefore no observable impacts on this parameter from the fish cages.

SRP concentration was lower (0.0015mg/l) at the site with cages (WIC) compared with the upstream (USC) site (0.0025mg/l) and the downstream DSC) site (0.0019mg/l). Nitrite-nitrogen levels varied minimally (0.031mg/l- 0.036mg/l) across the three study sites. Ammonia-nitrogen decreased only slightly from USC (0.066mg/l) through WIC (0.063mg/l) to DSC (0.053mg/l). Minimal differences in concentrations of these nutrient species between study sites suggest little or no impacts of fish cages on these parameters. Total suspended solids (TSS) were lowest (2.73mg/l) upstream (USC) and highest (5.01mg/L) downstream (DSC).This trend also suggest no impacts from the fish cages. It was noted that levels of all measured nutrient parameters were below those considered toxic to fish and other aquatic organisms.

Blue green algae was the dominant group in all study sites, with the highest biomass (6618 ug/L) recorded upstream of the cage (USC). The colony-forming algae (Microcytis Aphanocapsa), bead like algae (Anabaena) and filamentous algae (Planktolyngbya), contributed to the high blue green algal biomass.

As in all previous surveys, the zooplankton community was made up of Copepoda, Cladocera and Rotifera as broad taxonomic groups. Species richness was highest upstream of the cages (USC) with 17 species and lowest downstream of cages (DSC) with 8 species (Fig 1A). This observation was in stark contrast to most previous observations showing persistent depressions of species numbers at the sites with cages (WIC) (SON report 2011). Numerical abundance took a a comparable trend.

The macro-benthic community in the entire study area was composed of 5 broad taxonomic groups: Bivalvia, Gastropoda, Ephemeroptera, Diptera and Annelida. Compared to previous surveys, there was a general reduction in the overall macro-benthos abundances and number of taxa within the broad taxonomic groups across the three study sites. Diptera, Annelida and Ephemeroptera registered highest numerical densities (261, 9, and 163 ind.m-2 respectively) at the site upstream of the cages (USC). Gastropoda and Bivalvia (142 and 75 ind. m-2 respectively) attained highest abundance at the site downstream of the fish cages (DSC). Dipterans were the only group registering the lowest density (70 ind.m-2) at the site with cages (WIC). Overall, the highest abundance of macro-benthos (476 ind. m-2) occurred at USC while the lowest (322 ind. m-2) was recorded at WIC.

Haplochromines dominated the catch both by numbers (98.3%) and weight (75.1). Within the haplochromine species group, Astatotilapia species dominated the catch both by number (74.5%) and weight (61.8%). Lowest fish species diversity (1 species) was recorded at the site with cages (WIC) while highest diversity (3 species) was recorded at sites upstream (USC) and downstream (DSC) of the cages. Fish relative abundance (53.9%) was highest at the site with cages (WIC) and lowest (10.8%) downstream of the cages (DSC). Fish biomass was highest (53.3%) upstream and lowest (6.4%) downstream of the fish cages. In terms of numbers, catch rates were highest at the site with cages (WIC) at 14.2 fish per net and by weight at 264.6g per net upstream of the cages. Overall mean catch rates were 8.8 fish and 165.6g as compared to 0.7 fish and 144.6g recorded in September 2013. The increase in catch rates is attributed to the increase in haplochromine fishes recorded during the November 2013 survey.

Overall, the November 2013 survey results indicate no (serious) interference of the SON cage fish operations on the water environment quality and fish stocks in the survey area

1.0 BACKGROUND

It is an obligatory requirement of the National Environment Management Authority (NEMA) of Uganda to undertake regular environment monitoring at all sites conceived to be sensitive to the natural environment. Fish cage culture in natural water bodies, which is currently being promoted in Uganda, is one such area that requires regular environment monitoring by a competent environment agency. While quarterly monitoring surveys were undertaken at Source of the Nile (SON) fish farm in 2011, the client decided that NaFIRRI undertakes half-yearly surveys during 2012 and these were undertaken in June and December 2012. This year 2013, NaFIRRI reached agreement with the client to revert to the original quarterly surveys as these represent the more realistic intervals to track any possible negative developments resulting from the cage fish operations. The monitoring reports for the 2011 surveys and the most recent ones in June and December 2012 indicated no serious environmental perturbations at the site save for some evidence of incipient pollution effects especially at the lower production levels (algae, zooplankton and macro-benthos and these became apparent as the number of cages increased in the course of time (see 2011 and June & December 2012 SON survey reports). Suspected impacts included periodic algal blooms, reduced species diversity and numerical abundance of zooplankton, increase in abundance of pollution-tolerant macro-benthic forms (mollusks and dipteran larvae) and non-occurrence of the most pollution-sensitive macro-invertebrates (EPTs) at the transect with cages, WIC. These observations appear to suggest that as the number of cage units increase in any one culture site, there is a likelihood of development of negative impacts to both the natural water environment as well as sections of the aquatic biota. Environmental impacts may arise from bio-deposits of fish excretion, residual fish feeds, accumulation of faecal materials, pollutants etc, which may cause diurnal spells of low dissolved oxygen, algal blooms and many others (Nash (2001). Such localized stress factors, if persistent, can lead to negative changes in the in diversity, distribution and abundance patterns of some aquatic communities and environment quality, which if not checked, may affect fish production and productivity patterns in and around areas of fish cage operations.

During the year 2013, NaFIRRI started with the second quarter environmental monitoring survey in May 2013, having missed the first quarter survey due to late decision to switch from biannual to quarterly surveys. As in all previous surveys, the parameters investigated included water column depth profiles, Secchi depth transparency, selected physical- chemical parameters (water depth, column temperature, dissolved oxygen, pH, electrical conductivity); nutrients status (Soluble Reactive Phosphorus – SRP, Nitrite nitrogen- NO_2-N, Ammonium-nitrogen- NH_4-N and Total suspended solids- TSS); algae, zooplankton, macro-benthos and fish communities. These parameters are investigated at three sites including two reference sites and one site where the fish cages are located.. The first site/transect is located upstream of the cages (USC), the second site is within the cage rows (WIC) and the third is downstream of the cages (DSC).

The present report is the fourth quarter (Q4) report for the year 2013 and presents field observations made during the survey undertaken in November 2013. The report provides a scientific interpretation and discussion of the results with reference to possible impacts of the cage facilities to the water environment and the selected aquatic biota in and around the cage site. Survey conclusions are derived from the data generated and recommendations for cage operations in the lake are provided.

2.0 MATERIALS AND METHODS

Field measurements and sample collections were made at three points along each transect representing USC, WIC and DSC with respect to the location and areal spread of the fish cages. At each sampling point, thee replicate samples were taken for each parameter under investigation for the purpose of assessing variation in each parameter at each field site. Coordinate locations for each sample site were determined with a GPS device, recorded and used to prepare a site locations map (Figure 1).

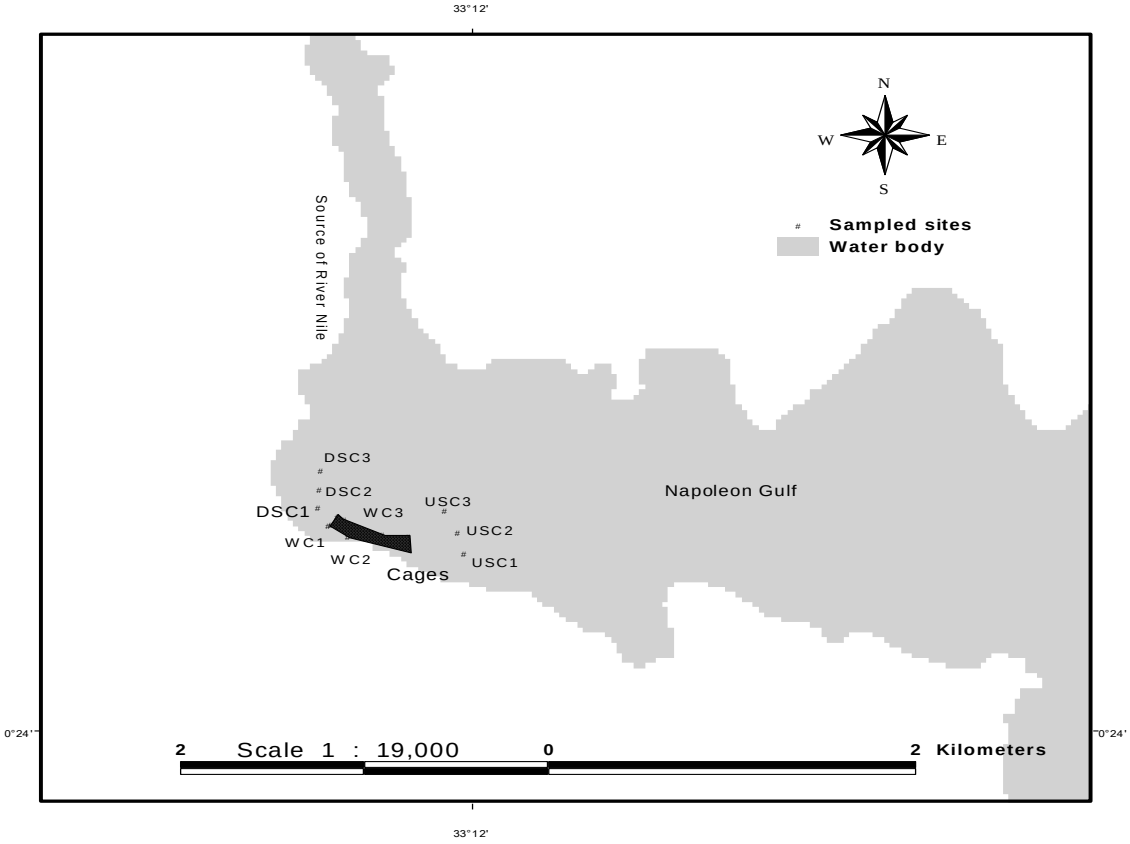

Figure 1. Map of the study area showing location of SON Fish Farm and study areas: USC- upstream of cages; WIC- within the cages and DSC- downstream of cages, at SON, in Napoleon Gulf, northern Lake Victoria.

2.1 Depth profiles and water transparency

A digital Echo Sounder was used to determine the total water column depth at each sampling point. A black and white Secchi disc harnessed with a 1-metre marked rope was used to determine water column transparency.

2.2 Physical-chemical environment

Physical-chemical parameters (water column temperature, dissolved oxygen, pH and conductivity), were measured in-situ with a pre-calibrated hydrolab containing a data logger at each site and the data down-loaded on to a computer for subsequent analysis.

2.3 Nutrient status

Water samples for the determination of nutrients and algal status were collected with a Van Dorn sampler, stored in clean, labeled plastic bottles. Water samples for determination of dissolved nutrients i.e. Soluble Reactive Phosphorus (SRP), Ammonium-nitrogen (NH_3-N) and Nitrite-nitrogen (NO_2-N) were filtered and analyzed by spectrophotometric methods following procedures by Stainton *et al*. (1977). Water samples were also analyzed for total suspended solids (TSS).

2.4 Micro-invertebrates (zooplankton) and Macro-invertebrates (macro-benthos)

The zooplankton community was sampled in triplicates at each sample point using a conical nitex plankton net of 0.25 metre mouth diameter and 60 µm mesh. Concentrated samples were placed in clean plastic bottles and fixed wit h 4% sugar- formalin. In the laboratory, samples were rinsed in tap water over a 50 µm nitex mesh and diluted to a suitable volume depending on the concentration of each sample. Series of 2, 2, and 5 sub-samples were taken from a well agitated sample using a calibrated automatic bulb pipette, each introduced on to a plankton counting chamber and examined under an inverted microscope at x100 magnification. Individual organisms were taxonomically identified using zooplankton taxonomic manuals by Boxshall & Braide 1991; Korinek 1999; Korovchinsky 1992; Koste 1978. Members of each species were enumerated and recorded and used to generate density estimates per unit area.

Macro-benthos community was sampled by taking sediment samples with a Ponar grab having open jaw area of 238cm^2, harnessed with a nylon rope marked at 1- metre intervals. Three grab hauls were taken from each sampling point and each kept separately for subsequent laboratory analysis. The bottom type and sediment texture were determined and described from visual observations and feel between two fingers. Each grab sample was concentrated, placed in clean, labeled sample bottle, and preserved with 5% formalin. In the laboratory, each sample was rinsed with tap water and spread on to a clean white plastic tray. Benthic organisms were sorted from the sediment using forceps and the sorted sample examined under a dissecting binocular microscope at x 400 magnification. Taxonomically identification was done using manuals by Pennak (1953), Mandhal-Barth, (1954) and Epler (1995). All taxa were recorded and individuals of each taxon enumerated.

2.5 Fish community

Three fleets of gill-nets comprising panels of mesh sizes 1" to 5.5" in 0.5" increments, and 6 to 8 in 1" increments were set overnight at USC, WIC and DSC. The nets were set between 1800hr and 1900hr on the date of the field day and removed between 0600hr and 0700hr the following morning.
Fish species caught by different nets in each fleet were sorted and identified as in Greenwood (1966). Some of the cichlid haplochromine fishes whose taxonomic identity could not be determined were in this survey, treated as a 'single species' group. For each fish species, the number, total weight (g) and individual total (TL) and standard (SL) lengths (cm) of the fish were measured and recorded. Fork length (FL) was measured for all fish species with forked caudal fins.

Biometric data (Total and Standard length, body weight, sex and gonad maturity state, stomach fullness and fat content) were determined and recorded for individual fishes. Fish stomachs were carefully removed placed in clean, labeled plastic sample bottles and preserved in 5% formalin for laboratory analysis of the contents as in Bagenal & Braun (1978). Fish specimens were also examined for any infection (parasitic or bacterial) both on the surface and within the gut cavity.

3.0 RESULTS, INFERENCES AND DISCUSSION OF DATA

3.1 PHYSICAL-CHEMICAL ENVIRONMENT

3.1.1 Total depth profile

Total depth across study sites was between 3.47m and 7.15m with USC as the deepest site and DSC as the shallowest (Fig.2). Compared to previous surveys, there were no marked variations in water depth across the study sites, providing no evidence of possible sedimentation from fish cage operations. However, this situation may have been influenced by possible flushing effect of the River Nile in the study area.

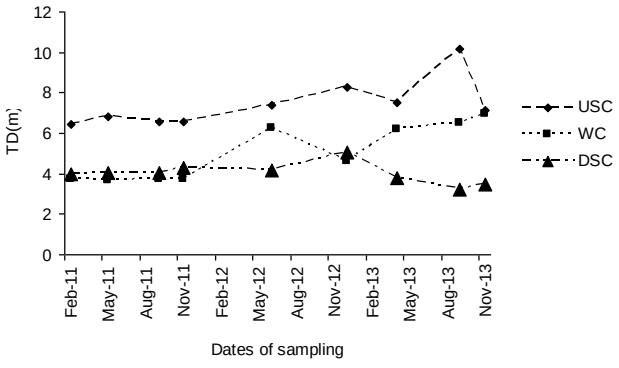

Figure 2. Total depth profiles at SON cage fish farm, February 2011-November 2013.

3.1.2 Secchi depth profile

Secchi depth (a measure of water column transparency largely due to suspended particles i.e. algae and /or silt) did not vary much (1.5-1.8m) across sampling sites and this range was comparable to past survey records. The site with cages (WIC) had the deepest secchi depth, indicating no possible impacts of the cages on water transparency in the area. It is noted that the observed range of secchi depth/water transparency was deemed as still good for cage fish production as well as natural organic productivity in the area.

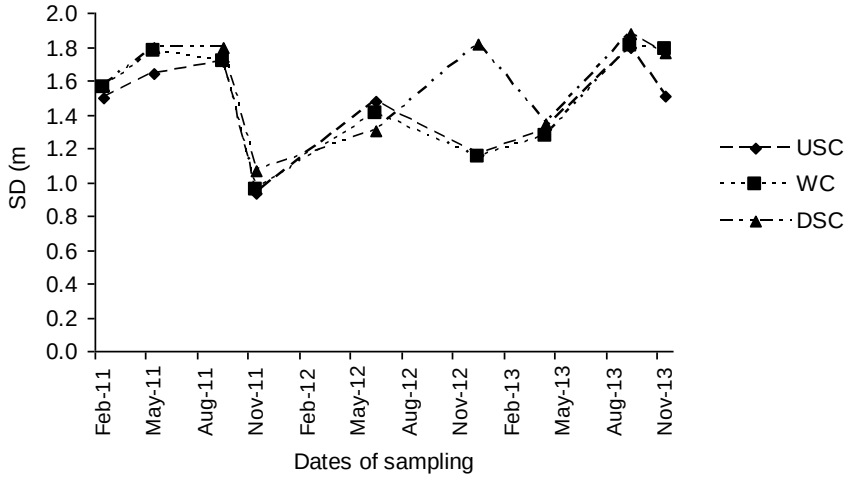

Figure 3. Variations in secchi depth profiles at SON during the sampling periods: February 2011-November 2013.

3.1.3 Turbidity profiles

Measured turbidity levels between 1.57 and 4.59NTU is considered low compared to 200 NTU, which is known to impact on fish negatively by impairing visibility as well as clogging fish gills.

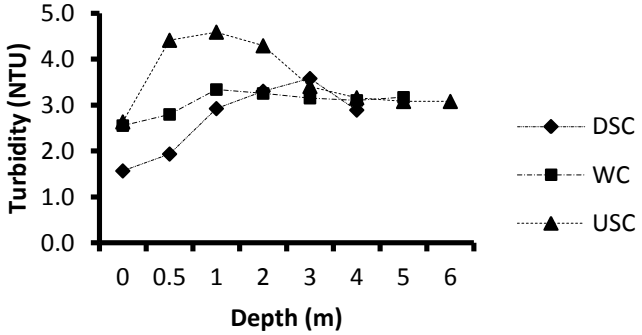

Figure 4. Trends in turbidity profiles at SON during the November 2013 period.

3.1.4 Dissolved Oxygen profiles

Dissolved oxygen concentration ranged between 6.94 and 9.10mg/L, a range well above the minimum level (3mg/L) for fish production and this oxygen concentration was well distributed along the entire water column, indicating that the lake water was well mixed.

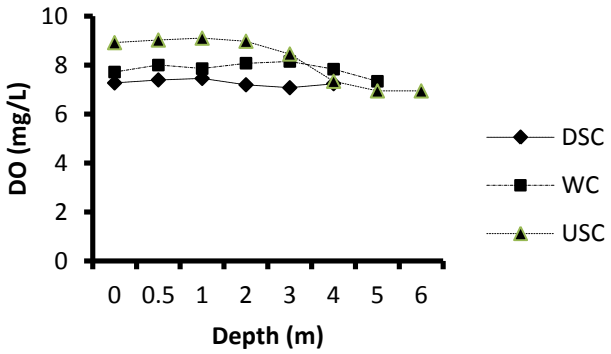

Figure 5. Trends in concentrations of dissolved oxygen across the study sites at SON, November 2013.

3.1.5 Temperature profiles

The measured temperature range (25.0 to 26.8°C) was within the optimal range for fish growth and spawning.

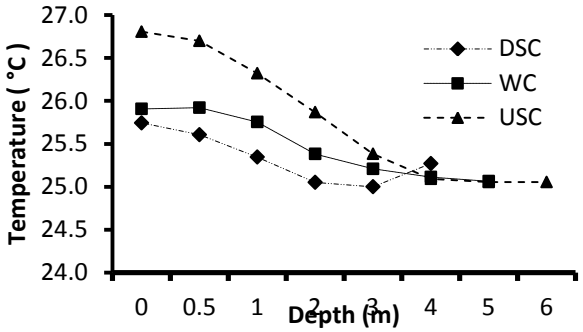

Figure 6. Trends in water temperature profiles across the study sites at SON , November 2013.

3.1.6 pH profiles

Measured values of pH ranged from 6.88 to 7.8 across the three sites and this range was within acceptable pH conditions for cage culture. Low pH below 5 is considered not favorable for fish health and production.

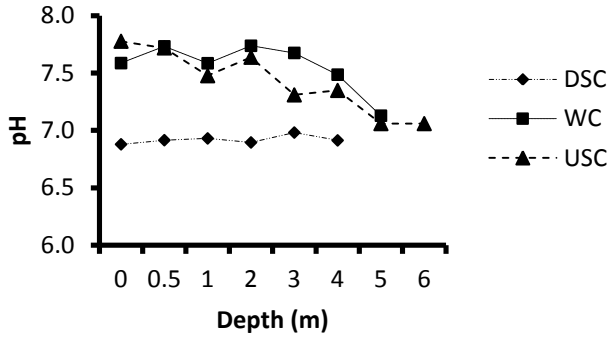

Figure 7. Trends in pH levels across the study sites at SON, November 2013.

3.1.7 Conductivity

Conductivity (an indication of the presence of dissolved ions in a water column) ranged between 111.3 and 120.0µScm^{-1} and fell within what is normally observed in Lake Victoria and most other fresh water bodies in Uganda. High conductivity values above 200 µScm^{-1} are an indication of more ions being released into the water from sources such as wastewater influx. There were thus no discernible impacts on this parameter from the fish cages.

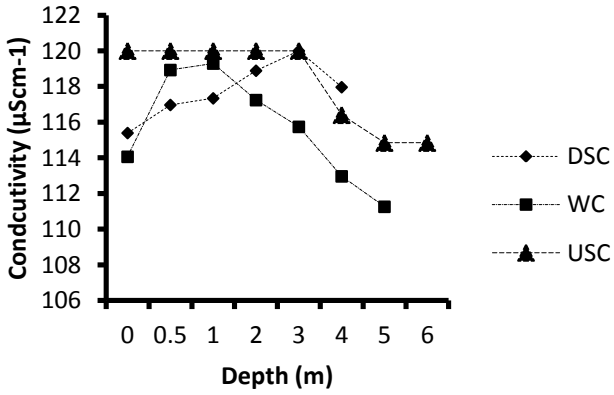

Figure 8. Trends in conductivity levels across the study sites at SON , November 2013.

3.2 NUTRIENT STATUS

3.2.1 Soluble reactive phosphorus (SRP)

This parameter was found to be highest upstream/USC (0.0025mg/l) probably due to eroded materials from the catchment but decreased slightly (0.0015mg/l) within the cages/WIC and increased (0.0019mg/l) downstream/DSC probably due to regeneration of phosphorus from bottom sediments Fig.9. The re-suspended phosphorus appeared to be re-distributed up to surface waters likely from overturn of the water column (Baldwin *et al* 2003).

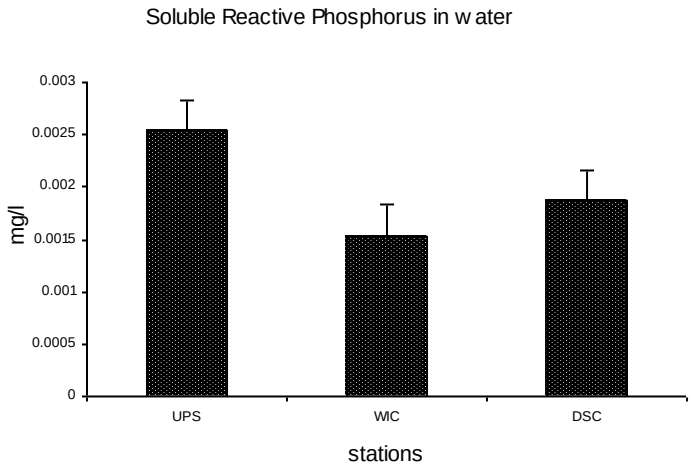

Figure 9. Trends of mean values of Soluble Reactive Phosphorus (SRP) at the 3 study sites at SON cage fish farm, November, 2013.

3.2.2 Nitrite-nitrogen (NO_2-N)

Levels of this parameter did not vary much at all study sites: 0.031mg/l USC, 0.033mg/l WIC and 0.036mg/l DSC (Fig.10). Nitrite is released as an intermediate product during the process of nitrification and denitrification (DWAF 1996c; Bronmark & Hanson, 2005), but is quickly converted to other more stable nitrogen ions (Yves, 1998). High levels are toxic to fish, animals and humans. The slight variations between the study sites suggested little or no impacts from the cage fish operations. The levels measured here were considered as not detrimental to fish (and other biota) growth and development.

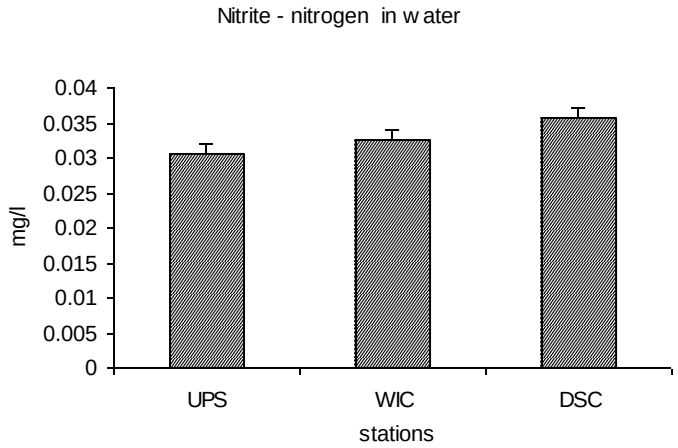

Figure 10. Trends in mean Nitrite-nitrogen values recorded at the study sites at SON cage fish farm, November, 2013.

3.2.3 Ammonium-nitrogen (NH_4-N)

Concentrations of this parameter ranged from 0.053mg/l at DSC through 0.063mg/l at WIC to 0.066mg/l at USC (Fig 11) probably as a result of bacterial decomposition of culture fish waste such as fish excretion and uneaten fish feeds (Moss, 1998; Wetzel, 2001). The slight increase shown at USC could have been caused by decaying debris along the shoreline.
Ammonia accumulation can be toxic and sub lethal effects are manifested in form of reduced growth rates and immunocompetence of the fishes.

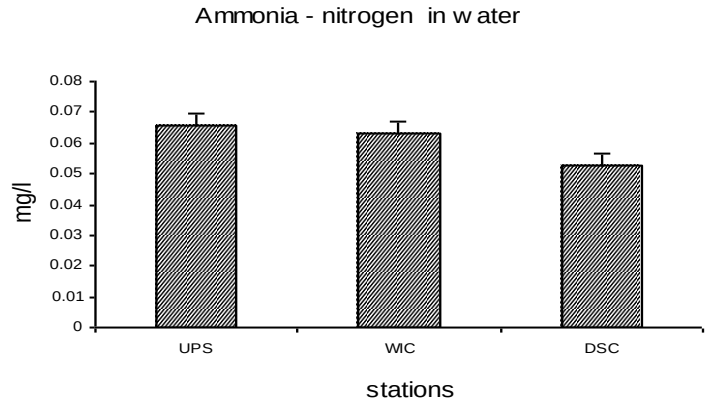

Figure 11. Trends in mean Ammonium-Nitrogen values recorded at the study sites at SON cage fish farm, November, 2013.

3.2.4 Total suspended solids (TSS)

.Total suspended solids (TSS) increased from 2.73mg/l (USC) through 4.43mg/l (WIC) to 5.01mg/L (DSC) (Fig.12). This was probably due to uneaten feeds and the presence of faecal

solids in the water coupled with eroded material from the sediment probably due to the flushing effect downstream by the River Nile current (Tlusty *et.al*. 2000).

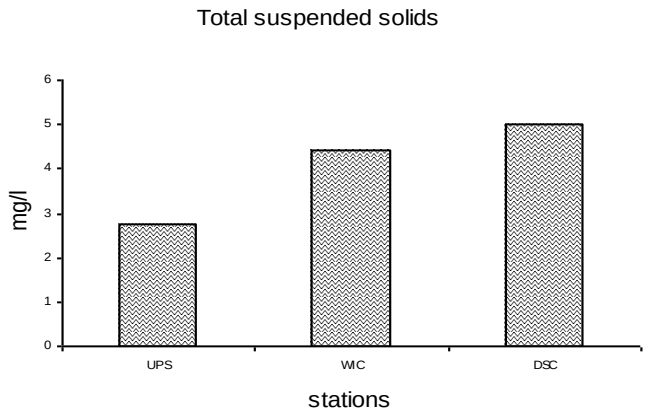

Figure 12. Variation of values of Total Suspended Solids (TSS) recorded at the study sites at SON , November, 2013.

The concentrations of nutrient parameters reported here were found to be below levels considered toxic to fish and other aquatic organisms according to Boyd (1996). The phosphate levels were surprisingly less than the normal range (0.1mg to 0.2mg/l) for sustenance of phytoplankton density **(**Sreenivasan, 1965); the natural food for tilapine fishes. Ammonia levels showed a similar pattern (ammonia is limited to 0.2 to 2.9mg/l (ionized ammonia (NH4+) for fish culture (Joseph *et al*, 1993). The concentration of total suspended solids (TSS) in all study sites was low (< 25 mg/l) according to Maitland (1990). The permissible levels by NEMA are: (Ammonia - nitrogen 10mg/l; Nitrite-nitrogen 2 – 20mg/l; Soluble Reactive Phosphorus 5.0mg/l and Total Suspended Solids 100mg/l) respectively. Thus the present results indicate that levels of the studied nutrients were below the maximum permissible limits and therefore not likely to alter the natural water environment or to be harmful to aquatic biota.

3.4 ALGAL COMMUNITY

3.4.1 Composition and biomass

Four major taxonomic groups (Blue green, Green, Diatoms and Dinoflagelletes) were encountered in the three study sites (Fig.13). Blue green algae constituted the dominant group in all study sites, with the highest biomass (6618 ug/L) recorded upstream (USC) of the fish cages. The colony-forming algae (*Microcystis* and *Aphanocapsa)*, the bead- like algae (*Anabaena) and* filamentous algae (*Planktolyngbya)* contributed to the high blue green algae biomass. *Nitzschia*, Navicula, *Cyclostephanodiscus* and *Synedra* dominated the diatom community while *Glenodinum* represented the Dinoflagelletes (Table 1). High diatom biomass (3557ug/L) was recorded downstream (DSC) compared to other sites while Green algae had the lowest biomass (698ug/L) at the site with cages (Fig. 13). A comparison between September and November indicated a stable species composition with a total of 45 for both months (Table 1).

Table 1. Species checklist in the major taxonomic algal groups in the study sites, Septemnebr & November, 2013**.**

Blue greens	**Sept**	**Nov**
Planktolyngbya circumcreta	**x**	**x**
Chroococcus limnetica	**x**	**x**
Chroococcus dispersus	**x**	**x**
Chroococcus spp		**x**
Aphanocapsa nubilium	**x**	**x**
Romeria spp	**x**	
Planktolyngbya limnetica	**x**	**x**
Planktolyngbya contorta		
Aphanocapsa incerta	**x**	**x**
Anabaena circinalis	**x**	**x**
Planktolyngbya tallingii	**x**	**x**
Merismopedia glauca	**x**	**x**
Chroococcus minutus	**x**	**x**
Pseudanabaena spp	**x**	**x**
Aphanocapsa spp	**x**	**x**
Aphanocapsa elachista	**x**	**x**
Coelomoron pusila	**x**	**x**
Coelomoron spp		**x**
Anabaenopsis tanganikae	**x**	
Cylindrospermopsis spp	**x**	
Cylindrospermopsis africana	**x**	**x**
Merismopedia tenussima	**x**	**x**
Coelosphaerium kuetzinganianum	**x**	**x**

Merismopedia elegans	**x**	**x**
Merismopedia gluaca		**x**
Cylindrospermopsis cuspis	**x**	
Aphanocapsa delicatissima	**x**	**x**
Microcystis spp	**x**	
Microcystis flos-aque		**x**
Chroococcus aphanocapsiodes	**x**	**x**
Cyanodycton spp	**x**	
Green algae		
Closterium acerosum	**x**	**x**
Scenedesmus perfolatus	**x**	**x**
Crucigenia fenestrata	**x**	
Ankistrodesmus falcatus	**x**	**x**
Closterium acerosum	**x**	
Monoraphidium contortum	**x**	**x**
Coelastrum costatum	**x**	
Oosystis gigas	**x**	**x**
Kirchneriella spp	**x**	**x**
Actinastrum hantzschii	**x**	**x**
Actinastrum spp		**x**
Ankistrodesmus setigerus	**x**	**x**
Pediastrum simplex	**x**	
Crucigenia fenestrata		**x**
Stuarastrum gracile		**x**
Selenastrum spp		**x**
Tetraedron trigonum		**x**
Diatoms		
Nitzschia acicularis	**x**	**x**
Nitzschia fonticola	**x**	**x**
Cyclotella spp	**x**	
Synedra cunnigtonii	**x**	**x**
Nitzschia nyassensis	**x**	**x**
Navicula gastrum	**x**	**x**
Cyclostephanodiscus spp		**x**
Aulacoseira granulata	**x**	
Epithemia spp		**x**
Dinoflagelletes		
Glenodinium spp		**x**
Total number of species	**45**	**45**

High algal biomass of blue green algae was recorded at USC site may have resulted from the high abundance of *Anabaena*, *Aphanocapsa* and *Planktolyngbya in* the samples at the time of

sampling. But also the upstream station had been shifted from the original site to another site close to Windy bay as the fish cage coverage had expanded and the number of cages up stream increased. Windy bay is less turbulent (ironically!) as such a stable biomass of algae may occur in this area compared to the nearby open area were the River Nile current is apparent. Low biomass of algae recorded at the site with cages maybe associated with high grazing rates by high densities of tilapia fishes in the cages given the recent cage additions in the area as algae constitutes the natural and preferred food of tilapine fishes.

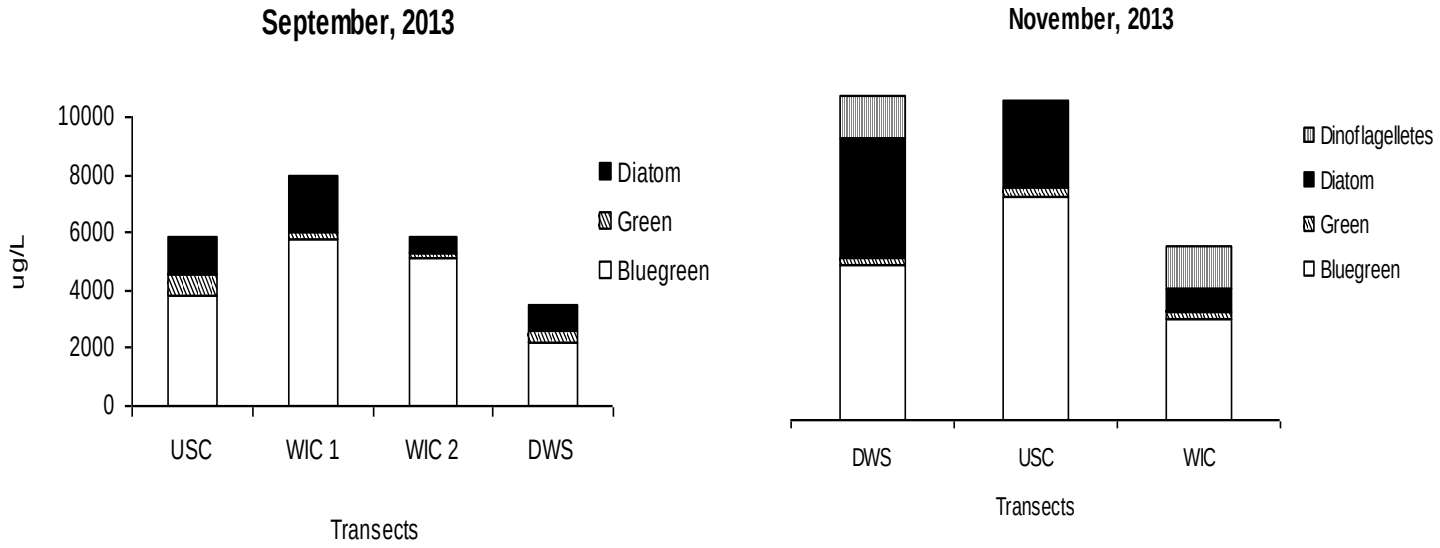

Figure.13 Relative contribution of major algal taxonomic groups to total wet algal biomas at the three study sites, September and November,2013**.**

The algal biomass in November was higher (6618ug/L) compared to the September biomass of 5797 ug/L (Fig. 13). A similar trend was observed in the diatom community with a biomass of 3557 ug/L in November and 1934 ug/L in September. For the green algae the reverse trend was observed with 253 ug/L in November and 711 ug/L in September (Fig. 13). These trends may be related to change of season because the time of the November field sampling coincided with tail end of the rainy season in the area, which probably may have influenced aspects of the lake chemistry. The higher diatom community appeared to have been driven by the occurrence of *Synedra cunnigtonii that* was non-existent in the September community.

Changes in algal biomass and composition have been documented in earlier records by Mugidde (1992) and may continue due to rampant disturbance of the lake ecotone zone that buffers the system from exogenous effects. Toxin-producing algae of the genera *Anabeana, Microcystis* and *Cylindrospsermopsis* may continue to occur so long as nutrient influx in the lake remains

unchecked coupled with new activities such as cage fish farming, which is commonly associated additional nutrients from uneaten feeds as well as excreta from the caged fishes.

3.5 ZOOPLANKTON COMMUNITY

3.5.1 Zooplankton composition, species richness and distribution patterns

The total zooplankton species number recorded was 24. Copepod species number ranged between 4 and 7, cladocerans 0 and 4 and rotifers 2 and 9. Total species number ranged between 8 and 17 (Fig 14A). Mean species numbers were 5.3, 1.9 and 12.2 for Copepoda, Cladocera and Rotifera respectively. Thus the zooplankton species richness was evidently driven by copepods and rotifers as previously reported in the August 2013 report. In the current survey, the total species richness was highest in the USC2 and USC3 (17 species) while the lowest (8 species) was recorded at DSC2 (Fig 14A). This observation was in contrast to previous surveys where persistent depression of species richness was a common feature at the site with cages (WIC) (see SON reports 2011). The most frequently encountered copepod species with 100% occurrence were: *Tropocyclops tenellus, Tropocyclops confinnis, and Thermodiaptomus galeboides* and this observation is consistent with most previous surveys **(Table 2).** Cladoceran species with frequency occurrence above 50% but less than 100% was only recorded for *Ceriodaphnia cornuta* while rotifers included *Euclanis* sp, *Keratella tropica, Syncheata* sp. and *Lacane luna* (Table 2). These features are comparable to other parts of the lake (Mwebaza-Ndawula et al 2003, Vincent et al 2011) without fish cages and may therefore not be attributed to presence of cages at SON fish farm.

Table 2. Zooplankton species composition, distribution and abundance across study sites at SON, November 2013

Sites	DSC1	DSC2	DSC3	WIC1	WIC2	WIC3	USC1	USC2	USC3	Max	Min	Mean	Percentage Occurrence
Copeppoda													
Mesocyclops sp.	1,617				337				2,425	2,425	337	1,459.6	33
Thermocyclops emini					505	674	1,213			1,213	505	797.2	33
T. incisus	707	1,635	126	539	168				2,021	2,021	126	866.0	67
T. neglectus	808	2,515	1,006	1,347	1,516	1,179	3,638	6,467	12,530	12,530	1,006	3,445.2	100
Thermodiaptomus galeboides	1,617	2,389	1,635	3,907	2,021	3,200	4,042	3,638	4,042	4,042	1,635	2,943.4	100
Tropocyclops confinnis	3,335	3,395	2,641	2,560	5,558	4,884	6,063	17,381	12,126	17,381	2,560	6,438.1	100
Tropocyclops tenellus	4,143	2,515	4,653	2,021	4,210	9,600	8,488	15,360	10,913	15,360	2,021	6,878.2	100
Calanoid copepodites	1,819	1,132		11,183	8,252	1,347	4,850	46,888	14,147	46,888	1,132	11,202.3	89
Cyclopoid copepodite	46,685	26,282	30,055	85,826	57,767	78,988	100,647	393,290	186,742	393,290	26,282	111,809.0	100
Nauplius larvae	111,762	47,534	52,816	262,193	169,765	407,908	543,249	1,488,276	820,532	1,488,276	47,534	433,781.7	100
Cladocera													
Bosmina longirostris							2,021	1,213	404	2,021	404	1,212.6	33
Ceriodaphnia cornuta	707			3,503	1,011	674		2,829	1,617	3,503	674	1,723.5	67
Daphnia lumholtzi(helm)					168		404			404	168	286.3	22
Diaphanosoma excisum					505			2,425	808	2,425	505	1,246.3	33
Moina micrura					842			2,425	1,617	2,425	842	1,628.0	33
Rotifera													
Asplanchna spp.								1,213		1,213	1,213	1,212.6	11
Brachionus angularis	606		2,264			842		2,425		2,425	842	1,534.3	44
Brachionus calyciflorus		880	1,258		842					1,258	842	993.3	33
Brachionus falcatus								2,021	808	2,021	808	1,414.7	22

Brachionus forficula								404		404	404	404.2	11
Euclanis sp	404		252	269		1,684		1,617	404	1,684	252	771.7	67
Filinia opoliensis				404			3,638	6,063	5,659	6,063	404	3,941.0	44
Keratella tropica	808		1,383	6,063	1,516	5,053	11,318	10,105	14,956	14,956	1,383	6,400.2	89
Lecane bulla		377	503	3,234	2,695	4,210		4,850	2,021	4,850	377	2,555.8	78
Polyarthra vulgaris.									808	808	808	808.4	11
Synchaeta spp.	2,122	755		1,347		2,021		3,638	4,850	4,850	755	2,455.5	67
Trichocerca cylindrica				943		1,011				1,011	943	976.8	22

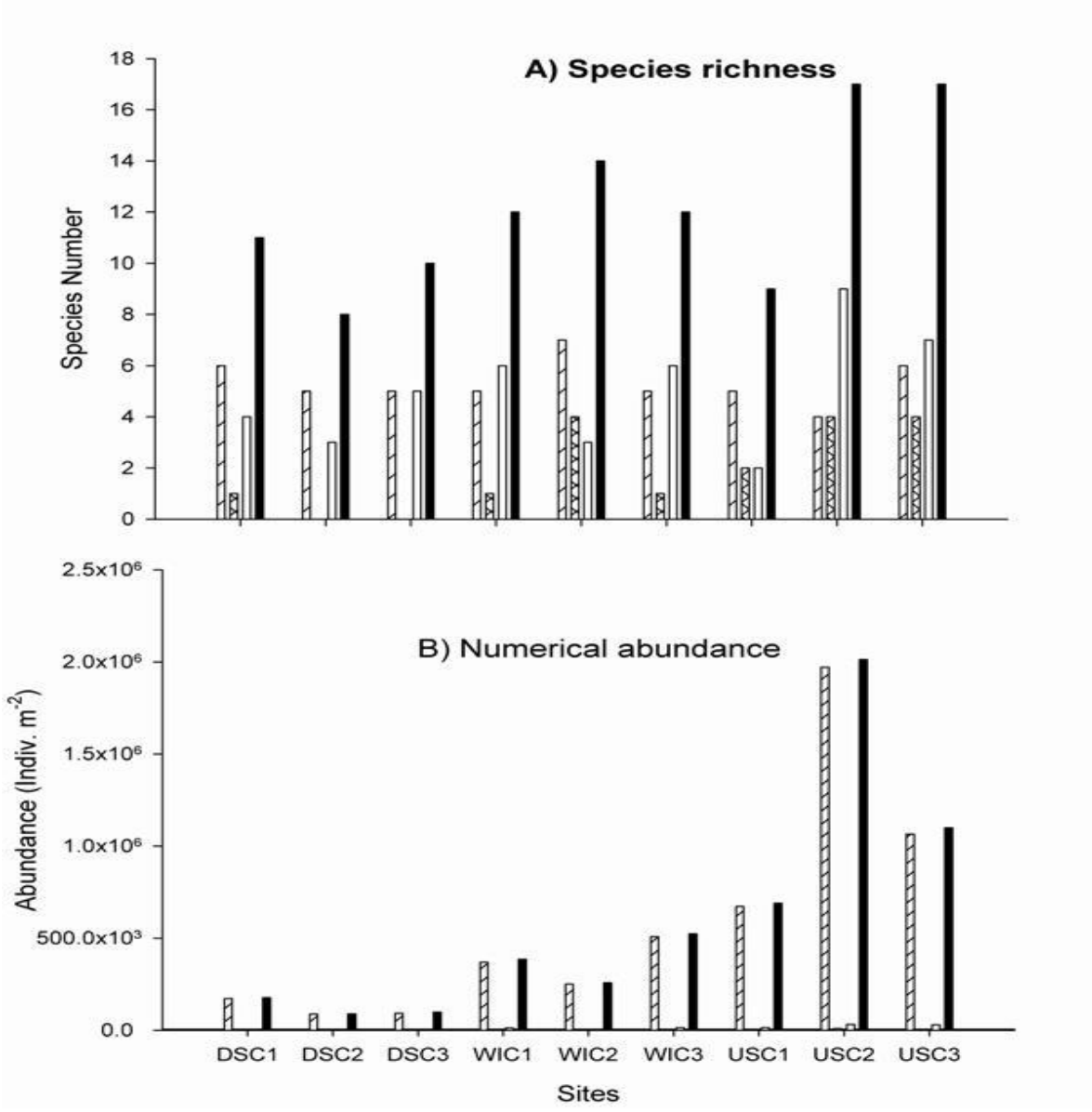

Figure 14. Zooplankton species richness and abundance across study sites, at SON cage fish farm, November 2013. Notice difference in the Y-axis scales.

There was an increasing trend of total abundance from DSC to USC sites (Fig 14B). Copepods where the main contributors of total abundance compared to Cladocera and Rotifera (Fig.14B), a feature typical of Lake Victoria zooplankton community (Mwebaza-Ndawula et al 2003, Vincent et al 2011). The rotifers which exhibited a decreasing trend from USC towards DSC in the previous survey (August 2013), showed no clear trend in the November reasults but ranged between 2,012 and 32,336; mean 13,393 Ind.m^{-2} (Fig.14B, Table 2). All groups (Copepoda, Cladocera and Rotifera) recorded lowest abundance (89,410 Ind. m^{-2}) at DSC2 and higher values

at USC2 (2,012,527 Ind. m^{-2}) and USC3 (1,099,432 Ind. m^{-2}) (Fig. 14B, Table 1), contrary to what was reported previously in the August report.

The expansion of the cage area (WIC) towards the upstream site (USC) may have influenced trend of species richness from the one earlier observed and (SON Survey reports, 2011); Mwebaza-Ndawula et al, 2013 Inpress). Such re-organization can lead to the development and spreading of effects resulting from fish feeds in the new cage areas. The expansion and stocking fish in cages was still ongoing by the time of sampling and thus may be associated with the reversed trends in the current data sets. The depression of species richness and abundance, which was previously observed at the site with cages (WIC), appeared to have shifted to the DSC (Fig. 14B) but consistency of the trend remains to be confirmed in future surveys.

However, eutrophic water bodies are commonly characterized by changes in phytoplankton productivity (i.e. development of algal blooms), fluctuations in pH, dissolved oxygen and conductivity levels, and a general decrease in aquatic biodiversity (Sekiranda *et al*., 2004, Tallberg *et al*., 1999, Cottenie *et al*., 2003, Hecky, 1993, Mazumder, 1994, Mugidde, 1993, Verschuren *et al*., 2002, Lungayia *et al*., 2001, Mavuti and Litterick, 1991). Changes in phytoplankton composition and productivity, are associated with structural changes in the food web and may affect the quality and quantity of phytoplankton composition and biomass *(Dodson et al*., 2000, Mugidde, 2004, Mwebaza-Ndawula, 1994, Tallberg *et al*., 1999, Cottingham, 1999), which in turn may alter zooplankton community structure leading to tolerant zooplankton species and algal herbivores becoming dominant (Gosselain *et al*., 1998, Gowen *et al*., 1992, Steiner, 2003).

The corresponding zooplankton species composition in the case of SON fish farm appear to be stable with the previously recorded species such as T*ropocyclops tenellus* and *T. confinnis* being still present in the community (Table 2). The rare organisms especially copepods (*Thermocyclops incisus* & *Mesocyclops* sp.) and most cladocerans , coupled with increasing prominence of small-bodied copepods (*Thermocyclops confinnis & Tropocyclops tenellus*) (Table 2) could be pointing to the predation pressure, where big prey are targeted (Brooks & Dodson, 1965), rather than impacts from the cage operations.

3.6 Macro-benthic community

3.6.1 Macro-benthos Composition

The macro-benthic community in the entire study area was composed of 5 broad taxonomic groups: Bivalvia, Gastropoda, Ephemeroptera, Diptera and Annelida (Table 3). Some of the groups that were encountered in previous surveys such as Trichoptera, Odonata and Decapoda were missing in the November 2013 field samples. A maximum of 14 taxa were recorded and this was a similar value as in the previous (September) survey. The order of relative abundance across all three study sites was: Diptera (45%), Gastropoda (27%), Annelida (18%), Bivalvia 1% and Ephemeroptera (1%).

Table 3. Occurrence of macro-benthic taxa at the three study sites at SON fish farm, 2011, 2012 and May 2013, Sept. 2013 and Nov. 2013

Taxa	Overall occurrence					Overall totals &%									
	Jun. 12	Dec. 12	May. 13	Sep. 13	Nov. 13	Jun.12		Dec. 2012		May.2013		Sep.2013		Nov.2013	
						Total	%	Total	%	Total	%	Total	%	Total	%
Bivalvia															
Byssanodonta parasitica	P	P	P	P											
Caelatura monceti	P		P	P	P										
Caelatura hauttecoeuri	P	P	P	P	P										
Corbicula africana	P	P	P	P	P										
.Mutera bourgguignati		P		P											
Aspatheria sp.			P	P	P										
Sphaerium sp.			P												
Sub total						1091	21	428	8	794	19	607	19	107	9
Gastropoda															
Bellamya unicolor	P	P	P	P	P										
Biomphalaria sp.			P												
Bulinus sp.	P	P	P	P											
Gabbia humerosa	P	P	P	P											
Melanoides tuberculata	P	P	P	P	P										
Anisus natalensis		P													
Sub total						1443	28	699	12	924	22	929	29	310	27
Ephemeroptera															
Caenis sp.	P	P	P	P											
Ephemerella sp.			P												
Povilla adusta	P	P	P	P	P										
Baetidae	P														
Leptophlebids	P		P	P											
Heptageniids	P														
Sub total						630	12	14	0	700	17	308	10	9	1

Trichoptera															
Leptocerids			P	P											
Psychomyiids	P	P	P	P											
Brachycentrids	P														
Lemnophilids	P		P												
Sub total						126	2	0	0	103	2	52	2	0	0
Plecoptera															
Perlids						0									
Odonata															
Libellulids			P	P		0	0	0	0	5	0	9	0	0	0
Diptera															
Ablabesmyia sp	P	P	P	P											
Chironomus sp.	P	P	P		P										
Clinotanypus sp.	P														
Cryptochironomus sp.				P											
Procladius sp.	P		P		P										
Tanypus sp		P	P	P	P										
Tanytarsus sp.	P	P	P	P	P										
Chironomins	P	P	P		P										
Ceratopogonids		P	P	P	P										
Chaoborus sp.	P	P	P	P	P										
Sub total						1106	21	4027	71	929	22	1032	32	521	45
Decapoda															
Caridina nilotica			P	P	P	0	0	0	0	0	0	5	0	5	0
Annelida															
Hirudines	P	P	P	P											
Oligochaetes	P	P	P	P	P										
Sub total						770	15	494	9	789	19	303	9	210	18
Overall number of taxa	**25**	**19**	**33**	**25**	**16**										
Overall means densities						**5166**		**5662**		**4244**		**3240**		**1162**	

3.6.2 Numerical abundance

Diptera, Annelida and Ephemeroptera registered highest numerical densities (261, 9, and 163 ind.m^{-2} respectively) at the site upstream of the cages (USC). Gastropoda and Bivalvia (142 and 75 ind. m^{-2} respectively) attained highest abundance at the site downstream of the fish cages (DSC). Dipterans were the only group registering the lowest density (70 ind.m^{-2}) at the site with cages (WIC). Overall, the highest abundance of macro-benthos (476 ind. m^{-2}) occurred at USC while the lowest (322 ind. m^{-2}) was recorded at WIC (Fig. 15).

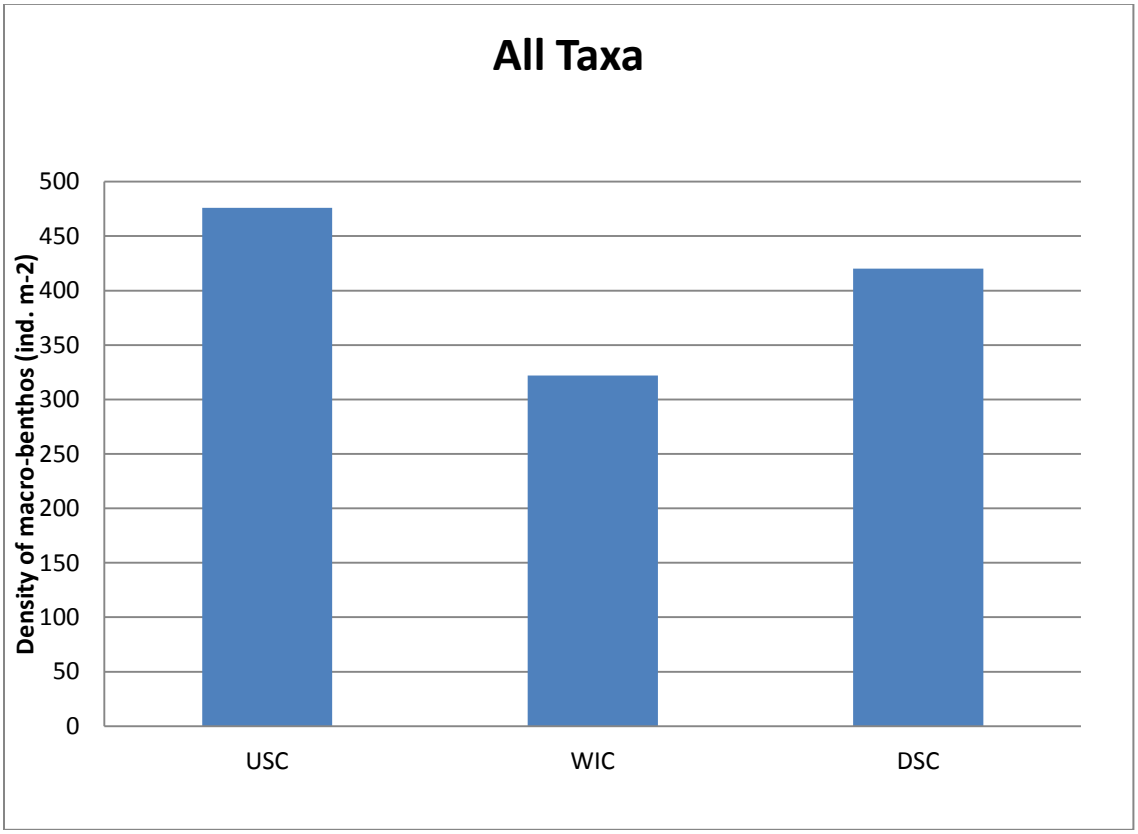

Figure 15. Variation of numerical abundance of macro-benthic broad taxonomic groups across study sites at SON cage fish farm, November 2013.

There was a general reduction in the overall macro-benthos abundances and number of taxa within the broad taxonomic groups across the three study sites. Among the most pollution sensitive group (ETPs), only one species, *P. adusta (*Ephemeroptera) was recovered; moreover at very low density (9 ind. m^{-2}). Like in December 2012, the current samples did not contain two key EPT component taxa: Trichoptera and Plecoptera in all three study sites. These observations are suspected to be signals of deteriorating water conditions although the persistence of the trend remains to be confirmed in subsequent monitoring surveys.

3.7 FISH COMMUNITY

3.6.1 Background

Studies on ecological impacts of cage fish farming on fresh water ecosystems are few but several investigations have accrued to marine ecosystems (Naylor *et al*., 2000). Thus, impacts upon wild fish stock close to culture cages in freshwater systems are generally not well known. The fish rearing operations at SON fish farm involve keeping Nile tilapia fish in cages under high stocking densities and feeding them on artificial (pellet) feeds. Napoleon Gulf being a shallow bay at the headwaters of the River Nile in Lake Victoria, harbors a wide variety of wild fish species that are cherished by riparian human populations. The wild fishes living close to cages are presumed to be affected by activities associated with this method of fish farming. Cage fish farming may affect the presence, abundance, and diet of organisms in the vicinity of the farm (Carss, 1990; Dempster *et al.,* 2002). Floating structures including cages may act as Fish Attracting Devices (FADs) as most pelagic fishes are known to be strongly attracted to floating objects (Freon and Dagorn, 2000; Castro *et al.,* 2002). Attraction to cage sites may be largely due to plenty of food available for the cultured fishes (Bjordal and Skar, 1992). As such, other ecological interactions between cultured and wild fish may be possible. Wild fish may be instrumental in cleaning the environment close to the cages through consumption of excess un-eaten food left by culture fishes. Caged fish under crowded conditions is vulnerable to water-borne diseases and could infect wild fish or vice versa. While diseases breaking out among cultured fishes may be controlled through treatment, diseases in wild fishes stocks may spread unabated and in severe cases can affect yields of a capture fishery.

3.6.2 Fish Catch composition

A total of 5 fish species, (including haplochromines (Nkejje) as a single species group), was recorded in the three study sites (Table 4) in the November 2013 survey. Haplochromines dominated the catch both by numbers (98.3%) and weight (75.1). Other fish species caught were *Lates niloticus, Oreochromis niloticus*, *Tilapaia zillii* and *Brycinus sadleri*. The lowest fish species diversity (1 species) was recorded at the site with cages (WIC) while the highest diversity (3 species) was recorded upstream (USC) and downstream (DSC) of the fish cage area. Fish abundance was highest (53.9%) at the site with cages and lowest (10.8%) downstream of the cages. Fish biomass was highest upstream (53.3%) and lowest downstream (6.4%) of the fish cages.

Table 4. Overall fish species composition

Site	Upstream		Within cages		Downstream		Overall	
Species	**% No**	**% Wt**	**% No**	**% Wt**	**% No**	**% Wt**	**% No**	**% Wt**
Lates niloticus	0	0	0	0	8.1	20.2	0.9	1.3
Oreochromis niloticus	0.8	42.2	0	0	0	0	0.3	22.5
Tilapia zillii	0.8	1.9	0	0	0	0	0.3	1.0
Haplochromines	98.3	55.9	100	100	89.2	77.9	98.3	75.1
Brycinus sadleri	0.0	0.0	0	0	2.7	1.9	0.3	0.1

3.6.3 Haplochromines

Six species of haplochromines were recovered during the November 2013 sampling (Table 5). Highest haplochromine diversity (5 species) was recorded from the upstream (USC) site and the lowest (4) from the downstream (DSC) and WIC sites, The haplochromines recorded during the November 2013 sampling belonged to four genera, namely *Ptyochromis, Psammochromis, Paralabidochromis and Astatotilapia.* The *Astatotilapia* species dominated the catch both by number (74.5%) and weight (61.8%). Haplochromine numerical abundance and biomass were highest at the site with cages (54.9% & 53.7% respectively) and lowest downstream of the cages (9.7% & 6.7%respectively).

Table 5. Composition and relative abundance of the haplochromines recorded in November 2013 survey at SON fish farm.

Site	Upstream		Within cages		Downstream		Overall	
Species	**% No**	**% Wt**	**% No**	**% Wt**	**% No**	**% Wt**	**% No**	**% Wt**
Ptyochromis sauvagei	0	0	4.9	7.7	0	0	2.7	4.1
Astatoreochromis alluaudi	0.8	3.4	0	0	3.0	2.5	0.6	1.5
Astatotilapia "thick lip"	0.8	0.6	0	0	0	0	0.3	0.2
Astatotilapia sp	75.6	64.1	73.5	58.8	75.8	71.6	74.5	61.8
Paralabidochromis "black para"	18.5	26.5	20.0	30.4	15.2	19.8	19.0	28.2
Psammochromis riponianus	4.2	5.3	1.6	3.1	6.1	6.2	3.0	4.2

3.6.4 Fish Catch rates/Biomass estimates

As a measure of standing biomass, catch rates i.e. catch per net per night was used to indicate relative abundance of fish species. To analyze gillnet performance; the nets and thus fish species were grouped into three categories. Category (A) consisted of fishes that grow to a small adult size and are caught by nets of up to 2.5" stretched mesh. Category (B) consisted of fish that could be retained by nets of up to 4.5" while category (C) was of large fish species capable of being caught in all the nets set.

In terms of numbers, catch rates were highest at the site with cages (WIC) at 14.2 fish per net and by weight at 264.6g per net upstream of the cages (Table 6). Overall mean catch rates during the period November, 2013 were 8.8 fish and 165.6g (compared to 0.7 fish and 144.6g recorded in September 2013**).** The increase in catch rates in November 2013 survey is attributed to the increase in haplochromine fishes.

Table 6. Catch rates (numbers and weight) of fish species recorded from SON FISH cages during November 2013

Site	**Upstream**		**Within cages**		**Down stream**		**Overall**	
Species	**Nos.**	**Wt (g)**	**Nos.**	**Wt (g)**	**Nos.**	**Wt (g)**	**Nos.**	**Wt (g)**
L. niloticus	0	0	0	0	0.2	6.5	0.1	2.2
O. niloticus	0.1	111.7	0	0	0	0	0.0	37.2
T. zillii	0.125	8	0	0	0	0	0.0	2.7
B. sadleri	0	0	0	0	0.25	2	0.1	0.7
Haplochromines	29.75	481	46.25	650.5	8.3	81	28.1	404.2
All species	**9.3**	**264.6**	**14.2**	**200.2**	**2.8**	**0.2**	**8.8**	**165.6**

Among the haplochromines, overall catch rate was 28.1 fish and 404.2g per net per night compared to 1.8 fish and 21.9g recorded in the previous survey of September 2013 (Table7). Catch rates were highest for *Astatotilapia* species both by number (20.9 fishes/net/night) and weight (249.7g/net/night).

Table 7. Catch rates (by number and weight) of haplochromine species recorded from SON FISH during November 2013 sampling.

Site	Upstream of cages		Within cages		Downstream of cages		Overall	
Species	**Nos**	**Wt (g)**	**Nos**	**Wt (g)**	**Nos**	**Wt (g)**	**Nos**	**Wt (g)**
Ptyochromis sp	0	0	2.25	50	0	0	0.8	16.7
A. alluaudi	0.25	16.5	0	0	0.25	2	0.2	6.2
A. "thick lip"	0.25	3	0	0	0	0	0.1	1.0
Astatotilapia sp	22.5	308.5	34	382.5	6.25	58	20.9	249.7
P. "black para"	5.5	127.5	9.25	198	1.25	16	5.3	113.8
Psammochromis sp	1.25	25.5	0.75	20	0.5	5	0.8	16.8
A11 species	**29.75**	**481**	**46.25**	**650.5**	**8.25**	**81**	**28.1**	**404.2**

3.6.5 Biology of common fish species

Basic biology of common fish species caught from the cage area in all sites sampled, during November 2013 is summarized in Table 8.

Table 8: Basic biological parameters of fish species caught SON Fish in November 2013

Species	No. examined	Size range (cmTL)	% mature	Food type
Lates niloticus	3	10.5 – 15.5	Nil	Empty
Oreochromis niloticus	1	44.3	Mature	Detritus, Algae
Tilapia zillii	1	14.5	Mature	Empty
Brycinus sadleri	1	8.7	Mature	Odonata, *Povilla* sp.
Astatoreochromis alluaudi	2	10.6 – 16.5	100%	Molluscs
Ptyochromis sauvagei	6	11.3 – 12.2	100%	Chironomids, chaoborids
Astatotilapia sp.	33	7.8 – 9.8	100%	Chironomids, Chaoborids
P.":black para"	19	7.8 – 11.8	100%	Chironomids, *Povilla* sp.
Psammochromis riponianus	8	9.4 – 13.2	100%	Chironomids

The importance of insects mostly chronomid and chaoborid larvae (Essami), and to some extent mollusks and *Povilla* sp. as an important forage item for up-coming haplochromine fishes is demonstrated. The apparent impoverishment of stocks of other fishes i.e. *Lates niloticus, Oreochromis niloticus Tilapia zilli* and *Brycinus sadleri* is inferred from the minimal catches of these species in the survey area.

All stomachs/guts of fishes examined in November 2013 survey did not contain pellet foods supplied/fed to the farmed fish. It can therefore be presumed that the farm management administered the fish food effectively. However, remnants of the artificial feeds, if any, were probably swept by the River Nile current downstream (DSC), which may attract fish in this area.

4. GENERAL SUMMARY

1. None of the measured physical-chemical parameters was found to be limiting to the survival and growth of the fish both in the cages and wild fish stocks in the area
2. Levels of the nutrient parameters investigated were below those considered toxic to fish indicating no impacts from the cage operations in the area.
3. High algal abundance observed in the study especially blue green algae is in agreement with previous survey observations and earlier studies and levels may serve as a natural source of feed to wild tilapine fishes in the area as well as supplementary feed for the culture cage fishes.
4. There was a general reduction in the overall macro-benthos abundances and number of taxa within the broad taxonomic groups across the three study sites but there was no clear evidence of possible impacts from the culture fish cages. .
5. Pollution tolerant macro-benthos such as Diptera, Oligochaete, Gastropoda and Bivalvia continued to be important in the study area although there was a general shift of abundance of macro-benthos from the site with cages (WIC) (see September 2013 report) to the upstream (USC) site
6. One EPT taxon (i.e. highly sensitive to pollution) macro-benthos especially Ephemeroptera was recovered albeit is small proportions and this observation was consistent with previous records in the area.
7. Zooplankton species diversity and abundance depression shifted from WIC to the upstream site (USC) and this observation was in contrast to previous observations depicting persistent depressions of zooplankton species richness at the site with cages (WIC).
8. *Haplochromines (Nkejje)* dominated the fish catch and contributed 98% of all the fishes caught compared to minimal contributions from other key species such as the Nile perch (0.9%) and the Nile Tilapia (0.3%).
9. The food recovered from guts of fishes caught did not indicate ingestion of the pellet foods fed to the cage fishes indicating good administration of the food to the culture fishes. Alternatively, any feed remnants could have been swept downstream by the River Nile current.
10. Insect food items especially larvae of chaoborids and chiironomids underscored the importance of insects in the current food chain and nutritional support of up-coming haplochromine fishes in the study area and probably the entire lake at large. There was no evidence of fish cage operations impacting on the occurrence of natural fish food items for both the caged fishes and wild fish populations.

5. CONCLUSIONS

1. Investigated physical-chemical parameters including nutrient status indicate a fair/good natural water environment, suitable for both cage and wild fish production in the area
2. Observed high algal biomass especially of the blue-greens is a common and widespread phenomenon in and around shallow near-shore areas of Lake Victoria and may not necessarily be attributed to fish cage operations at SON fish farm
3. Occurrence in high abundance of certain forage food items such as algae, zooplankton (especially copepods) and dipteran larvae suggests normal development of the key natural fish food organisms in the survey area and is a sign of non-interference of the fish cage operations in natural fish food production
4. Dipteran larvae diversity and abundance are evidently important for nutritional support of especially up-coming haplochromines and other fishes in the area
5. Overall, the November 2013 survey results indicate no (serious) interference of the SON cage operations on the water environment quality and fish stocks in the survey area.

6. RECOMMENDATION(S)

Regular monitoring of key aspects of the water environment and aquatic biota need to be sustained in and around the fish cages for the purpose of early detection of any possibility of environment change, which if not mitigated early, may compromise environment quality with consequences to aquatic production and productivity. This recommendation is particularly important given the current trends of fish cage expansion in the area by SON as potential impacts are likely to develop with more cage numbers in any one place.

7. REFERENCES

Bagenal, T. and E. Braum 1978. Methods of assessment of fish production in freshwaters. IBP Handbook 3. Blackwell Scientific Publications, Oxford. (3rd edition).

Baldwin, D.S., Whittington, J & Oliver, R. 2003. Temporal variability of dissolved P speciation in eutrophic reservoir-implications for predicting algal growth. Water Research 37: 4595-4598

Bjordal, A., & Skar, A.B. 1992. Tagging of saithe (*Pollachius virens* L.) at a Norwegian fish farm: preliminary results on migrations. *ICES Council Meeting Papers 1992/G* 35.

Boyd, C.E. 1996. Environmental Impact Statement for Ecologically Responsible Shrimp Farming Project in the Rufigi delta Tanzania prepared for the African Fishing Company LTD Dar es salaam, 112

Bronmark, C. & Hansson. 2005. The Biology of lakes and Ponds. Oxford University Press. Oxford.

Brooks, J. L. (1957) The systematics of North American *Daphnia*. *Memoirs of the connecticut academy of Arts and Sciences,* 13**,** 1-18.

Brooks, J. L. & Dodson, S. I. (1965) Predation body size and composition of the plankton. *Science,* 150**,** 28-35.

Carmello L., Juan, M. H., & Miguel L.S., 2008. The effects of water temperature in aquaculture management. Vol 38, Issue 18

Carss, D.N. 1990. Concentration of wild fish and escaped fishes immediately adjacent to fish farm cages. *Aquaculture* 90:29-40.

Castro, J.J., Santiago, J.A., & Santana-Ortega, A.T. 2002. A general theory on fish aggregation to floating objects: an alternative to the meeting point hypothesis. *Reviews in Fish Biology and Fisheries* 11:255-277.

Cohen, D. and E. Lahav. Tilapia production in shrimp ponds: Salinity tolerance and polyculture. Aquaculture Production Technology (Israel) Ltd., P.O.Box 4330, Jerusalem, Israel

Cottenie, K., Michels, E., Nuytten, N. & Meester, L. D. (2003) Zooplankton metacommunity structure: Regional vs Local processes in highly interconnected ponds. *Ecological Society of America***,** 991-100.

Cottingham, K. L. (1999) Nutrients and zooplankton as multiple stressors of phytoplankton communities: Evidence from size structure. Limnology Oceanography, 44, 810-827.

Dias, J. D., Takahashi, E. M., Santana, N. F. & Bonecker, C. C. (2011) Impact of fish cage-culture on the community structure of zooplankton in a tropical reservior. *Iheringia Serie Zoologia,* 101**,** 75 - 84.

Demir, N.; Kirkagac, M. U.; Pulatsu, S. & Bekcan, S. 2001. Influence of trout cage on water quality, plankton and benthos in an Anatolian Dam Lake. The Israeli Journal of Aquaculture-Bamidgeh 53:115-127.

Dempster, T., Sanchez-Jerez, P., Bayle-Sempere, T., Gimenez-Casalduero, F., & Valle, C. 2002. Attraction of wild fish to sea cage fish farms in the south-western Mediterranean Sea: spatial and short-term temporal variability. *Marine Ecology Progress Series* 242:237-252.

Dodson, S. I., Arnott, S. E. & Cottingham, C. L. (2000) The relationship in lake communities between primary productivity and species richness. *Ecology,* 81**,** 2662-2679.

DWAF, 1996a.Soth African Water Quality Guidelines. Volume 7: Aquatic Ecosystems, Pretoria.

Epler, J.H 1995. Identification Manual for Chironomide of Florida Revised edition.

Freon, P., & Dagorn, L. 2000. Review of fish associative behaviour: towards a generalisation of the meeting point hypothesis. *Reviews in Fish Biology and Fisheries* 10:183-207.

Greenwood, P.H. 1966. *The Fishes of Uganda.* The Uganda society, Kampala. (2^{nd} ed,). 131 pp.

Greenwood, P.H. 1981. The haplochromine fishes of the east African lakes. Collected papers on their taxonomy, biology and evolution with an introduction and species index. New York. Cornell university press. 939 pp.

Gosselain, V., Viroux, L. & DEscy, J. P. (1998) Can a community of small-bodied grazers control phytoplankton in rivers? *Freshwater Biology,* 39**,** 9-24.

Gowen, R. J., Tett, P. & Jones, K. J. (1992) Predicting marine eutrophication: the yield of chlorophyll from nitrogen in Scottish coastal waters. *Marine Ecology Progress Series,* 85**,** 153-161.

Hargreaves, J.A. 1998. Nitrogen biogeochemistry of aquaculture ponds. Aquaculture 166: 181-212.

Heather D. R., (2012). Why Water Quality Control is Critical to the Fish Farmer, © 2013 Aquaculture Directory, NISA Media, Aquaculture Scoop

Hecky, R. E. (1993). The eutrophication of Lake Victoria. *Verhandlungen des Internationalen Verein Limnologie,* 25**,** 39-48.

Joseph K. B., Richard W. S. ,Daniel E. T. (1993). An introduction to water chemistry in freshwater aquaculture, University of Massachusetts Dartmouth North Dartmouth Massachusetts 02747. NRAC Fact Sheet No. 170-1993.

Lungayia, H., Sitoki, L. & Kenyanya, M. (2001) The nutrient enrichment of Lake Victoria (Kenya waters). *Hydrobiologia springer Netherlands,* 458**,** 75 - 82.

Loren Larkin, K. 1995. Save Our Streams- Monitor's Guide to Aquqtic Macroinvertebrates , 2nd edition. Izaak Walton League of America.

Luz, Rebecc, R., Martinez-Alvares, R., DE pedro, N., & Delgado, M., 2008. Growth, food intake,
regulation and metabolic adaptations in goldfish (Carassius auratus) exposed to different salinities, Aquaculture 276: 171 – 178.

Lungayia, H., Sitoki, L. & Kenyanya, M. (2001) The nutrient enrichment of Lake Victoria (Kenya waters). *Hydrobiologia springer Netherlands,* 458**,** 75 - 82.

LVEMP 2001. Gillnet survey records Kiryowa station, Napoleon Gulf, Lake Victoria. Unpublished NaFIRRI data November 2001 and April 2002.

Mandahl-Barth, G. 1957. Intermediete hosts of Schistosoma African Biomphalria & Bulinus . Bull World Health Organisation 16(6):1103-63.

Mandahl-Barth, G. 1957. Intermediete hosts of Schistosoma African Biomphalria & Bulinus . Bull World Health Organisation 17(1): 1-65.

Maitland, P.S.: Biology of Fresh Waters. 269pp. Chapman and Hal l.USA (1990).

Mandahl-Barth, G. 1954. The Freshwater Mollusks of Uganda and adjacent Territories.

Mavuti, K. M. & Litterick, M. R. (1991) Composition, distribution and ecological role of zooplankton community in Lake Victoria, Kenya waters. *Verhandlungen des Internationalen Verein Limnologie,* 24**,** 1117 - 1122.

Mazumder, A. (1994) Patterns of algal biomass in dominant odd-link vs even-link lake ecosystems. *Ecology,* 75**,** 1141-1149.

Merritt, R. W. and Cummins, K. W 1997. An introduction to the Aquatic Insects of North America, 3rd edition. Kendall/Hunt Publishing Co., Dubuque, Lowa.

Moss, B. 1998. Ecology of Fresh Waters: man and medium, past to future. Third Edition. Blackwell Science Ltd. Oxford.

Mugidde, R. 1992. Changes in phytoplankton primary productivity and biomass in Lake

Victoria (Uganda). MSc.Thesis. Department of Botany, University of Manitoba, pp 86.

Mugidde, R. (1993) The increase in phytoplankton primary productivity and biomass in Lake Victoria (Uganda). *Verhandlungen des Internationalen Verein Limnologie,* 25**,** 846-849.

Mugidde, R. (2004) Changes in phytoplankton communities and primary production. IN BALIRWA, J. S., MUGIDDE, R. & OGUTU-OHWAYO, R. (Eds.) *Challenges for Management of the Fisheries Resources, Biodiversity and Environment of Lake Victoria.* First ed., Fisheries Resources Research Institute.

Mwebaza-Ndawula, L., V. Kiggundu & W. Pabire Gandhi (2003). Diversity and abundance if invertebrates in the Victoria basin lakes and their role in fishery production. Uganda Journal of Agricultural Sciences 8: 209-220

Mwebaza-Ndawula, L. (1994) Changes in relative abundance of zooplankton in northern Lake Victoria, East Africa. *Hydrobiologia,* 272**,** 256-264.

Namulemo G. 1997. Distribution, relative abundance and food of the surviving haplochromine cichlids in the littoral areas of Napoleon Gulf of (Lake Victoria). MSc. Thesis. Makerere University, Kampala Uganda 89 pp.

Nandini, S., Valdez, M. H. & Sarma, S. S. S. (2005) Life History Characteristics of Cladocerans (Cladocera) Fed on Wastewaters *Acta hydrochimica et hydrobiologica,* 33**,** 133-141.

Nash, C.E.(editor). 2001. The net-pen salmon farming industry in the Pacific Northwest. U.S. Dept. of Commer., NOAA Tech. Memo. NMFS-NWFSC-46.

Naylor, R., Goldburg, R., Primavera, J., Kautsky, N., Beveridge, M., Clay, C., Folke, C., Lubchenco, J., Mooney, H., & Troell, M. 2000. Effects of aquaculture on world fish supplies. *Nature* 405:1017-1024.

Ogutu-Ohwayo, R. 1985. The effect of predation by Nile perch, *Lates niloticus* (Linne) introduced into lake Kyoga (Uganda) in relation to the fisheries of Lake Kyoga and Lake Victoria. FAO Fish rep. No. 335 18-41.

Okello,W.,C.Portmann, Erhard, K.Gadenmann & R.Kurmayer 210a. Occurrence of microcystine-producing cyanobacteria in Ugandan fresh water habitats. Environmental toxicology 25:367-380

Pace, M. L. (1986) An emprical analysis of zooplankton community size structure across lake trophic gradients. *Limnology Oceanography,* 31**,** 45 - 55.

Pennak, R.W. 1989. Freshwater invertebrates of the United States. John Wiley & Sons, New York.

Pennak, R. W. (1953) *Fresh-water invertebrates of the United States,* New York, John Wiley & Sons.

Radwan, S. & Popiolek, B. (1989) Percentage of rotifers in spring zooplankton in lakes of different trophy. *Hydrobiologia,* 186/187**,** 235-238.

Rutner-Kolisko, A. (1974) *Planktonic rotifers: Biology and taxonomy,* Biological Station Lunz of the Austrian Academy of Science. E. Schweizerbart'sche Verlagsbuchhandlung.

Sars, G. O. (1895) *An account of the Crustacea of Norway,* Christiania and Copenhagen Alb. Cammermeyer Forlag

Sekiranda, S.B.K., J. Okot-Okumu, F.W.B. Bugenyi, L.M. Ndawula and P. Gandhi 2004 Variation in composition of omacro-benthic invertebreates as an indication of water quality status in three bays in Lake Victoria. Ug. J. Agr. Sci. 9:396-411.

Sitoki, L., R.Kurmayer,E. Rott. (magezi) Spatial variations of phytoplanktion composition, biovolume and resulting microcystin concentrations in the Nyanza gulf (Lake Victoria,Kenya)

Sladecek, V. (1983) Rotifers as indicators of water quality. *Hydrobiologia,* 100**,** 169-201.

Stainton, M. P., M.J. Capel and F.A .J. Armstrong. The Chemical Analysis of Fresh Water, 3rd Ed.

Sterner, R. W. & Hessen, D. O. (1994) Algal Nutritient Limitation and the Nutrition of Aquatic Herbivores. *Ann. Rev. Ecol,* 25**,** 1.

Steiner, C. F. (2003) Keystone predator effects and grazer control of planktonic primary production. *OIKOS,* 101**,** 569-577.

Tallberg, P., Horppila, J., Vaisanen, A. & Nurminen, L. (1999) Seasonal succession of phytoplankton and zooplankton along a trophic gradient in a eutrophic lake implications for food web management. *Hydrobiologia,* 412**,** 81-94.

Sreenivasan, A.: Limnology and productivity of tropical upland impoundments in Nilgiris, Madras state India. Phycos., 7(1). 146-160 (1965).

The National Environmental (Standards for Discharge of Effluent into Water or Land) Regulations S. I. No. 5/1999 (Under Section 26 and 107 of the National Environmental Act, cap 153)

Tlusty, M.F., Snook, K., Pepper, V.A. & Anderson, M.R. 2000. The potential for soluble and transport loss of particulate aquaculture wastes. Aquaculture Research 31: 745-755

Verschuren, D., Johnson, T. C., Kling, H. J., Edgington, D. N., Leavitt, P. R., Brown, E. T., Talbot, M. R. & Hecky, R. E. (2002) History and timing of human impact on Lake Victoria, East Africa. *The Royal Society,* 269**,** 289-294.

Vincent, K., Mwebaza-Ndawula, L., Makanga, B. & Nachuha, S. (2012) Variations in zooplankton community structure and water quality conditions in three habitat types in northern Lake Victoria. Lakes & Reservoirs: Research & Management, 17, 83-95

Wetzel, G.R. 2001. Limnology. Lake and River Ecosystems. Third Edition. Academic Press. San Diego.

Yves Collos, 1998. Nitrate uptake, nitrite release and uptake and new production estimates. Marine Ecology Progress Series, Vol.b171: 293-301

Zanatta, A. S., Paerbiche-Neves, G., Ventura, R., Ramos, I. P. & Carvalho, E. D. (2010) Effects of a small fish cage farm on zooplankton assemblages (Cladocera and Copepoda: Crustacea) in a sub-tropical reservoir (SE Brazil). Pan-American Jour